AUTOMOBILE IDLE EXHAUST EMISSIONS

1981 VANCOUVER TEST PROGRAM

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A Joint Project Of

MINISTRY OF ENVIRONMENT
BRITISH COLUMBIA

and

ENVIRONMENT CANADA

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PREFACE

In June 1981 the Ministry of Environment of British Columbia conducted a joint vehicle testing program in cooperation with Environment Canada and the Ministry of Transportation and Highways of British Columbia. The program was conducted at one of the Vehicle Testing Stations in the Vancouver area. The purpose of the program was to determine the emission characteristics of the vehicle fleet and investigate the need for an inspection/maintenance program to reduce auto emissions in British Columbia.

The report describes the results of the test program and recommends that consideration be given to implementing a motor vehicle emission inspection program in specific areas of the Province.

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1. INTRODUCTION

The air quality data in the Vancouver area indicate that on several occasions the ozone levels exceed the Federal air quality objectives[1]. The concentration of ozone in ambient air, according to well established scientific sources[2], is directly related to the quantity of vehicle exhaust emissions in air. It was therefore decided to undertake a test program to determine the relative state of tune and emission characteristics of a sample vehicle fleet in Vancouver. For this purpose one of the existing safety test lanes (Bidwell Street Station) was selected and 400 vehicles were tested in June 1981.

A variety of vehicle parameters and data were recorded to form a data bank of the vehicle population in Vancouver. This data was then used to analyze the emission characteristics of the fleet and to indicate the improvements possible with corrective maintenance including the added advantage of better fuel economy.

2. EQUIPMENT AND TEST PROCEDURES

Previous investigations[3,4,5,6] have shown that idle emission tests can be used as a measure of the relative emission and fuel consumption condition of a vehicle. As a result, for this study, it was decided that emission measurements using infra-red hydrocarbon (HC) and carbon monoxide (CO) analyzers would be made at idle.

Vehicle-specific idle emission standards to determine acceptability of carbon monoxide (CO) and hydrocarbon (HC) levels in the exhaust were set at either manufacturers specifications or at the value obtained from the following equations[7]:

6 and 8 cylinder: $CO\% = 0.5 + \frac{\text{age (years)}}{10}$

4 cylinder: $CO\% = 2.5 + \frac{\text{age (years)}}{10}$

$HC = 300 + \text{age (years)} \times 30$

These equations provide estimates of emission levels from a properly tuned vehicle.

The following information was recorded during the test for each vehicle:

- model year
- manufacturer
- number of cyclinders
- HC and CO levels at idle
- acceptability of emissions
- exhaust gas re-circulation (EGR) information
- distance travelled per year

3. RESULTS

3.1 MODEL YEAR, MANUFACTURER AND ENGINE SIZE DISTRIBUTION

In order to cover a reasonable cross-section of the vehicle population in Vancouver a total of four hundred vehicles were tested during the program.

Table 1 presents the distribution of vehicles by model year, manufacturer and engine size. It can be observed from this table that out of the four hundred vehicles tested:

i) 173 of the vehicles, or 43%, are 7 years old (1975) or older;
ii) 157 of the vehicles, or 39%, are 4 cylinder vehicles; and
iii) 149 of the vehicles, or 37%, are imported (Japanese and European) vehicles.

TABLE 1
MODEL YEAR, MANUFACTURER AND ENGINE SIZE DISTRIBUTION

MODEL YEAR	MANUFACTURER						ENGINE SIZE				
	GM	FORD	CHRY.	AMC	JAP.	EURO.	4 CYL.	6 CYL.	8 CYL.	OTHER	TOTALS
1982	1	0	0	0	0	0	1	0	0	0	1
1981	20	2	2	1	15	2	20	10	12	0	42
1980	21	4	2	0	12	6	19	13	12	1	45
1979	17	4	4	1	4	6	11	7	18	0	36
1978	17	7	6	1	5	11	18	7	21	1	47
1977	5	3	3	0	7	6	13	1	10	0	24
1976	13	4	2	1	8	4	14	4	14	0	32
1975	10	7	3	0	1	4	6	6	13	0	25
1974	11	10	3	1	3	6	12	7	15	0	34
1973	3	5	2	1	6	8	12	5	8	0	25
1972 (older)	21	13	16	4	14	21	31	25	33	0	89
Total	139	59	43	10	75	74	157	85	156	2	400

Compared to similar surveys conducted in other Canadian cities the present survey indicates that Vancouver has:

i) 10 to 15% higher population of 7 years or older vehicles;
ii) 20 to 30% higher population of 4 cylinder vehicles; and
iii) 27 to 32% higher population of imported vehicles.

3.2 VEHICLE AGE AND KILOMETREAGE DISTRIBUTION

Table 2 shows percent distribution of the vehicles tested and vehicle kilometres travelled (VKT) by these vehicles according to the age of the vehicles. It can be observed from this table that out of the four hundred vehicles tested:

i) 171 vehicles, or 43%, are less than four years old; and
ii) approximately 50% of the total VKT by the fleet is accounted by the newer vehicles, i.e. less than four years old.

TABLE 2

% DISTRIBUTION OF VEHICLE AND VEHICLE KILOMETRES TRAVELLED (VKT) BY VEHICLE AGE

AGE	NO. OF VEHICLES TESTED	AVERAGE ANNUAL KILOMETRES	% OF TEST FLEET	% OF TOTAL VEHICLE KM TRAVELLED (VKT)
1	43	21 300	10.5	13.9
2	45	23 200	11.3	16.2
3	36	14 840	9.0	8.3
4	47	16 230	11.8	11.7
5	24	15 290	6.0	5.6
6	32	14 660	8.0	7.2
7	25	14 700	6.3	5.6
8	34	18 340	8.5	9.6
9	25	18 150	6.3	7.0
10+	89	10 840	22.3	14.9
		AVERAGE = 16 120		

A comparison of these numbers with the surveys conducted in other Provinces of Canada is presented in Table 3. The Province of B.C. along with Manitoba has relatively less % of newer vehicles (43%) and also less % VKT compared to some of the other provinces.

TABLE 3

CANADIAN %AGE DISTRIBUTION OF LESS THAN 4YEARS OLD VEHICLES AND VEHICLE KILOMETERS TRAVELLED

PROVINCES	% VEHICLES LESS THAN 4 YEARS OLD	% OF TOTAL VKT BY VEHICLES LESS THAN 4 YEARS OLD
B.C.	43	50
Alberta	53	58
Manitoba	44	50
Quebec	51	54
P.E.I.	65	67

The survey also indicates that the average kilometres travelled per year by vehicles in the fleet in B.C. is about 16 120 km. A comparison of this figure with surveys conducted in other provinces is shown in Table 4.

TABLE 4

COMPARISON OF AVERAGE KILOMETRES TRAVELLED PER YEAR

PROVINCE	AVERAGE KILOMETRES TRAVELLED PER YEAR BY A FLEET VEHICLE
B.C.	16 120 km
Alberta	18 785 km
Manitoba	14 615 km
Quebec	17 381 km
P.E.I.	19 435 km

3.3 EMISSION PERFORMANCE BY MODEL

Table 5 shows the average concentration of carbon monoxide (CO) and hydrocarbon (HC) in the exhaust at idle of the vehicles tested by model year.

The following observations can be made from this table:

a. The average CO level in the exhaust is 2.88%.
b. The average hydrocarbon concentration in the exhaust is 275 parts per million (ppm).
c. 46% of the vehicles are at specification (i.e. emissions are considered to be at acceptable levels).

"% @ Spec" is a key statistic indicating a measure of acceptability of the emission values. For Vancouver 46% of the vehicles were judged acceptable while in other surveys this was only 25-30%. This may be due to the fact that the Vancouver fleet consisted of more 4-cylinder engines which normally have higher acceptability levels of CO%.

TABLE 5

EMISSION PERFORMANCE BY MODEL YEAR

MODEL YEAR	NUMBER	IDLE % CO	IDLE PPM HC	% @ SPEC.
1982	1	0	40	100
1981	42	0.72	112	76
1980	45	1.66	158	67
1979	36	1.90	185	69
1978	47	2.42	244	47
1977	24	3.26	269	46
1976	32	2.64	278	44
1975	25	2.62	360	40
1974	34	3.53	288	26
1973	25	4.37	401	40
1972 & older	89	4.59	403	24
Total =	400	AVG. 2.88	AVG. 275	AVG. 46%

3.4 IDLE EMISSIONS BY ENGINE SIZE

Table 6 is similar to Table 5 but it breaks down emissions by engine size. Table 6 indicates that there is little difference in idle emissions among the different size engines, however a much higher percentage of the 4 cylinder engines are at specification. This is directly due to the higher acceptability levels for the small engines. Since the total exhaust volume is generally proportional to the engine size, the larger vehicles emit more total emissions than their smaller counterparts. The different vehicle size groups all have about the same CO concentration in the exhaust, but the exhaust volume for these smaller engines is lower. Thus total emissions from smaller engines is lower that than from larger engines at equivalent exhaust concentrations.

TABLE 6

EMISSION PERFORMANCE BY ENGINE SIZE

NUMBER OF CYLINDERS	NUMBER	CO %	HC PPM	% @ SPEC.
4	157	2.80	273	59
6	85	3.05	228	34
8	156	2.91	305	40
Other	2	0.2	73	100
	TOTAL = 400	AVG. 2.88	AVG. 275	AVG. 46

3.5 EMISSION PERFORMANCE BY MANUFACTURER

Table 7 compares the emission performance of the different manufacturer groups. Based on the "% @ spec" the GM, Japanese and European vehicles are the best performers for the test fleet. This is generally consistent with the results of the other studies.

TABLE 7
EMISSION PERFORMANCE BY MANUFACTURER

MANUFACTURER	NUMBER	CO	HC	% @ SPEC.
GM	139	1.93	228	54
Ford	59	3.20	279	36
Chrysler	43	4.51	345	23
AMC	10	3.28	290	40
Japanese	75	2.58	224	57
European	74	3.73	370	43
TOTAL =	400	AVG. 2.88	AVG. 275	AVG. 46

3.6 EXHAUST GAS RECIRCULATION

The oxides of nitrogen (NO_x) is an exhaust pollutant formed during combustion which can be reduced by recirculating a small portion of the exhaust into the combustion chamber. This has been one of the main methods of controlling NO_x since 1973 and is called EGR (exhaust gas recirculation). The hardware itself is simply a valve that opens under certain engine operating conditions. When this valve is disabled, the exhaust emissions of NO_x double[8]. During the present survey, the operation of these valves was checked.

Tables 8, 9 and 10 show EGR tampering by age, manufacturer and engine size. The 4-cylinder engines are the lowest users of EGR because these engines can generally meet the federal NO_x standards without EGR. Since these 4-cylinder engines are predominantly of Japanese and European manufacturers, EGR use by these manufacturers is much lower than the North American manufacturers.

The GM, Japanese and European vehicles had the lowest incidence of EGR tampering which coincides with being the better performers. EGR tampering also appears to be age related with more tampering being evident in the older models. Of all EGR equipped vehicles tested, 67 (28%) had their EGR system disabled. This means that 17% of the fleet is emitting double the normal amount of NO_x.

TABLE 8

EGR TAMPERING BY MODEL YEAR

MODEL YEAR	NUMBER	EGR EQUIPPED	EGR OPERATIONAL	% TAMPERED
1973	25	11	4	64
1974	34	27	14	48
1975	25	22	9	59
1976	32	26	18	31
1977	24	14	6	57
1978	47	35	24	31
1979	36	29	25	14
1980	45	35	34	3
1981	42	36	34	6
1982	1	1	1	0
TOTAL	311	236	169	AVG. 28

TABLE 9

EGR TAMPERING BY MANUFACTURER

MANUFACTURER	NUMBER	EGR EQUIPPED	EGR OPERATIONAL	% TAMPERED
GM	139	113	89	21
Ford	59	45	27	40
Chrysler	43	25	13	48
AMC	10	5	1	80
Japanese	75	35	29	17
European	74	13	10	23
TOTAL	400	236	169	AVG. 28

TABLE 10

EGR TAMPERING BY ENGINE SIZE

NUMBER CYLINDERS	NUMBER	EGR EQUIPPED	EGR OPERATIONAL	% TAMPERED
4	157	66	51	23
6	85	55	45	18
8	156	115	73	37
Other	2	0	0	0
TOTAL	400	236	169	AVG. 28

4. EMISSION REDUCTION POTENTIAL

When discussing the motor vehicle as a major source of air pollution, one normally speaks in terms of the mass of pollutants emitted from the exhaust. In order to determine the mass of pollutants, concentrations of CO and HC need to be converted to "grams/mile". This conversion is virtually impossible since both driving cycle and control technology affect the emission rates of different vehicles.

However, based on laboratory testing and previous test programs conducted by Environmental Protection Service, Environment Canada, there appears to be an emission reduction potential for the Vancouver fleet of 40% for CO, 15% for HC and 15% for NO_x if all vehicles were operating properly.[9] Presented in Table 11 are the following:

i) estimates of total emissions CO, HC and NOx expressed as NO_2 for 1976[10] in B.C.; and

(ii) estimates of potential reductions in the emissions of CO, HC and NO_x that can be expected per year provided all the vehicles are operating properly and the exhaust emissions are within the specifications of the manufacturers.

TABLE 11

ESTIMATES OF EMISSIONS AND POTENTIAL REDUCTIONS IN EMISSIONS OF CO, HC AND NOx IN BRITISH COLUMBIA, GASOLINE-POWERED MOTOR VEHICLES, 1976

POLLUTANT	1976 EMISSIONS TONNES	EMISSION REDUCTION POTENTIAL	
		%	TONNES
CO	936 495	40	374 598
HC	111 918	15	16 788
NO_x	66 617	15	9 992
TOTAL	1 115 030	36%	401 378

According to a nationwide inventory of emissions of air contaminants[9], the gasoline-powered vehicles account for approximately 53% of total emission inventory in B.C. As can be seen in Table 11, a suitable inspection and maintenance program can provide a potential reduction of 36% in the emissions from the gasoline-powered vehicles. This would lead to a net reduction of about 19% in the total emission inventory of B.C. Since the formation of oxidants depends on the amount of HC and NO_x a sizeable reduction in the level of oxidants can be expected.

5. FUEL CONSUMPTION CONSIDERATIONS

Carbon monoxide is a by-product of combustion that results when there is not sufficient air available for complete combustion of the fuel. High CO levels in the exhaust indicate excessive fuel flow or restricted air flow both of which cause excessive fuel consumption. The idle test is unfortunately not an accurate measure of fuel consumption because each person drives a different route or cycle and the amount of time the idle circuit is in effect varies from vehicle to vehicle. However, one can safely say that if the idle CO% is high a certain amount of fuel is being wasted.

Figure 1 shows a graphical relationship between Fuel/Air (F/A) ratio and percent carbon monoxide (% CO) by volume on dry basis. It is apparent from this graph that % CO in the exhaust increases very rapidly as the Fuel/Air (F/A) ratio increases.

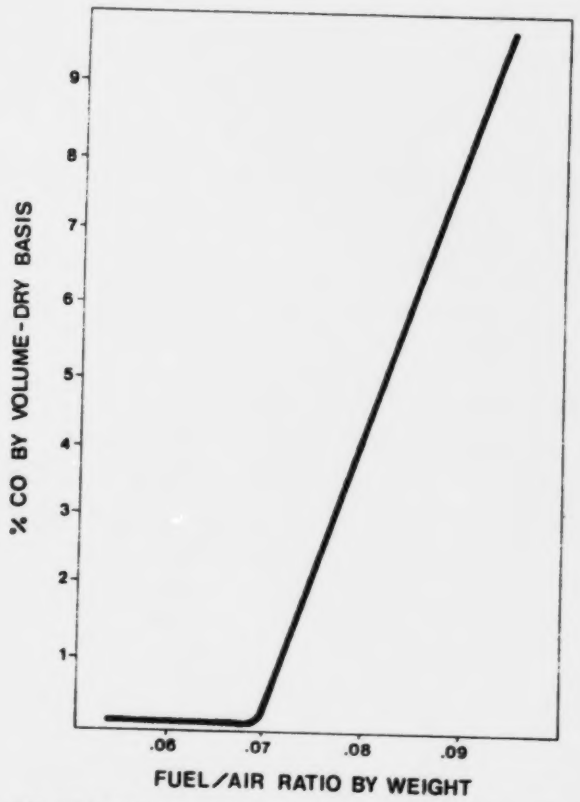

FIGURE 1. RELATIONSHIP OF FUEL/AIR RATIO WITH CO LEVELS[11].

For example at a CO% of 4.0, the F/A is 0.078. If the CO% was lowered to a more reasonable value of 0.5%, the F/A would be 0.070. This translates into a 10% saving of fuel at idle only. If the driving cycle is heavily oriented to low speeds with stop and go operation as one could experience in a city, then the idle circuit of the carburetor would be operational during a large portion of the cycle.

FUEL SAVING POTENTIAL

Based on the studies conducted by Environment Canada on the effect of emission-oriented maintenance on fuel economy/consumption proper maintenance (where required) can improve the average fuel economy of the fleet of repaired vehicles by[7]:

5.5% in urban driving conditions;
1.8% in highway driving;
4.4% in combined conditions.

The present survey indicates that approximately 54% of the vehicles are not adjusted to manufacturers specifications (largely carburetor maladjustments). If one were to use a 50% capture ratio standard, then a total fleet fuel saving of over 2% could be realized.

It is estimated that in 1981 the gasoline consumption in British Columbia amounted to approximately 4.2×10^9 litres. Assuming 2% saving in fuel consumption, a price of 40¢/litre, and a program that covers 50% of the vehicle population in B.C., a potential annual saving of approximately $16.8 million dollars is probable.

6. CONCLUSIONS

1. 46% of the fleet tested was performing satisfactorily on the basis of emissions of HC and CO.

2. 28% of the exhaust gas recirculation (EGR) valves tested were inoperative. This would result in a 17% increase in fleet NO_x emissions for the tested fleet.

3. Proper tuning could reduce fleet emissions by 40% CO, 15% HC, 15% NO_x.

4. 22% of the Vancouver fleet is over 9 years old and almost 40% of the vehicles have 4 cylinder engines; 37% are imported vehicles.

5. The 6 and 8 cylinder engines are polluting at higher levels than the 4 cylinder engines.

6. Older vehicles have higher emission levels than newer ones and have their control systems tampered with more. The older vehicles, however, travel less number of miles annually than the newer ones.

7. The GM, Japanese and European vehicles are better performers with lower levels of emissions than the other vehicles.

8. Assuming an inspection and maintenance program that covers 50% of the vehicle population in B.C. and a conservative figure of 2% saving in fuel consumption, it is estimated that a potential saving of appproximately $16.8 million can be expected annually.

7. RECOMMENDATIONS

Based on the emission testing program conducted on a sample vehicle fleet in Vancouver, it is recommended that a joint study should be undertaken by the British Columbia Ministry of Environment and Ministry of Transportation and Highways to determine the feasibility of developing and implementing an acceptable Inspection and Maintenance Program for the Greater Vancouver area in order to improve and prevent any further deterioration of the ambient air quality in that area.

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LIST OF APD RESOURCE DATA

The RESOURCE DATA is one of four Regular Publication series produced by the Assessment and Planning Division. RESOURCE DATA presents information collected and expressed in map and/or tabular form.

APD RESOURCE DATA 1 - References on Cadmium, Copper, Lead and Zinc in the Freshwater Environment: Supplementary Report to Effects of Dissolved Metals on Aquatic Biota of the Lakes of the Campbell River Watershed. Colin. J.P. McKean.